WIP: Measuring the Impact of Design Problem Solving on Diversity, Equity, and Inclusion in ECE Classes

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***Abstract*—This work-in-progress research-to-practice paper describes a study of the effects of design problem solving on diversity, equity, and inclusion in Electrical and Computer Engineering classes. Design problems promote design thinking which entails students thinking about how to deploy new knowledge to come up with solutions. In this study, the effect of design problem solving on diversity, equity, and inclusion, is examined as 52 students have faced challenges of design problems in an electrical and computer engineering class.**

***Keywords*—design problem solving, diversity, equity, and inclusion.**

I. Introduction

Creativity is inherent in the nature of design problems [1]. Bound only scientific knowledge and problem constraints, design thinkers use their human imagination to generate various possibilities as valid solutions to the same stated design problem. Deciding between alternative solutions is the next step of design solving. Chandrasekaran in 1989 informed that the design problem does not have a unique solution. Alternative solutions can be derived analytically or recalled from memory by designers with different mental capacities, or a final possibility is to originate them through a creative process in the designer's mind [1]. Additionally, depending on the problem-solving approach, every step-in design conceptualization can split into different alternatives, or sometimes even, bud off to a new idea for a solution. This inevitably results in diverse solutions that are mentally envisaged possibilities that design thinkers identify and can evaluate.

It is the aim and research question of this study to identify the impact(s) of design problem solving on Electrical and Computer Engineering (ECE) classrooms' diversity, equity, and inclusion (DEI). Fifty-two students were surveyed by the end of this spring semester of 2024 to evaluate their experience solving design problems in a sophomore-level ECE course. The surveys' results reveal that the students have experienced a sense of equity and self-efficacy working on the design project. The diversity generated by design problem solving is evident in the solutions of the students to the design problem that reflect their both knowledge and consciousness. Moreover, the diversity is marked in the students' responses to the surveys, along with a fostered sense of equity and inclusion.

II. The Formulation of the Engineering Design Problem Inherently Lends Itself to Diversity, Equity, and Inclusion

Several theories and a host of articles discuss the importance of design problem solving for learning and professional practice [2-4]. Design problem solving enhances cognitive skills, enhances knowledge [2], and motivates design students to engage in learning activities [5, 6]. Design students are braver at risk taking as they indulge in decision making during the design processes [7], which better prepares them for future careers [8]. It is also well-established that design thinking innovates societies, increases students' sense of self-efficacy [9], and promotes diversity, and inclusion [10, 11].

The design problem comprises a list of system requirements, or specifications that are formulated to be met by the designer. Several solutions can be posed to solve the stated problem, but a smaller subset of these solutions can be considered optimal. Engineering problems are usually subject to constraints that can limit the designer's choices and render many solutions non-optimal, or even non-viable. Fig. 1 shows the steps of an engineering design problem.

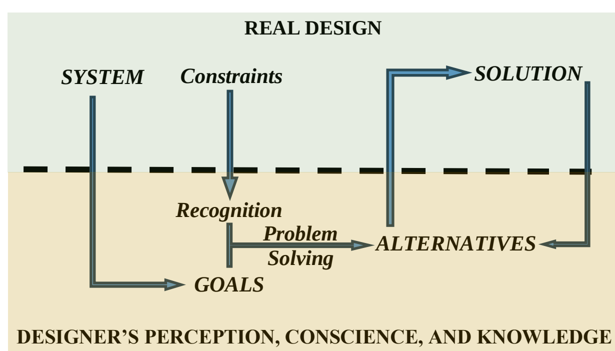

Fig. 1. Elements of design problem solving (modified from [1, 12]).

To solve the design problems the students must tailor their solutions to the design specifications of the problem, identify the design constraints, and produce innovative solutions [13].

The designer's perception affects the way the designer perceives a problem and accordingly shapes the way design decisions are made. Moreover, the solutions can vary not only according to each student's grasp of the material, but also according to their diverse history, socio-economic backgrounds, and/or conscience and understanding of the universal technologies and present situations.

The engineering students then represent the solution which in ECE contexts can encompass schematics, models, written codes, implemented hardware, calculated variables, or simply verbal statements. After the implementation of the design plans, the implementation is tested, both qualitatively and quantitatively, to validate functionality. A few iterations are expected to optimize the design and solution. Fig. 1 summarizes the engineering design problem solving process. It is evident that design problems, as presented above, possess many merits in comparison to analytical problems. Design students will experience, firsthand; the value of their work, boosting self-efficacy through divergent problem solving; adopt design principles that have good impact on society; and accept that there can be a multitude of correct answers, which increases sense of diversity and inclusion.

Design thinking modules are expected to improve students' participation in class as they engage as designers and not analyzers of theory. Design problems are also expected to help students better understand electronics circuits topics and prepare them for subsequent advanced topics in electronics [2, 4].

III. Introduction of Design Modules in An Elementary ECE Course

In this work-in-progress study, the researchers instruct ECE classes spanning all rankings from sophomore to senior grades. Some of these courses are design in nature, like capstone project course, and analog and digital electronics design courses. Other courses, especially the sophomore-level courses which are customarily analytical in nature, do not have design components either in lectures or in labs. For the purpose of this study, the researchers have modified two sophomore-level courses to incorporate design components. Lectures and laboratory experiments have been revamped to systematically allow students to encounter design problems earlier in their ECE study. The students were also introduced to the elements of an engineering design problem, presented in the previous section.

By the last month of the semester, and in one of the revamped courses, a microprocessors programming and interfacing course, the students were tasked to complete a design project working on a team. The students were surveyed at the end of the semester to gage their experience of working on engineering designs.

A. *Diverse Designs*

Fifty-two students worked in 17 teams to develop prototypes as solutions to one design problem posed by the instructor. The researchers assessed students' designs in terms of correctness, divergence, and whether it conforms to a standard, or has considered a qualified impact and other performance metrics. The first metric, correctness, was judged by the instructors as the efficacy of the proposed designs and implements prototype to meet with the design problem system requirements, and work around the engineering design constraints. Divergence of the solution was judged as the ability of the team of students to produce a design that reflected their background and personality. The proposed designs were also judged by a third metric; the students' evaluation of the impact(s) of their solutions on non-technical contexts. Design solutions impacts of non-technical context, aligned with ABET criterion-III student outcome-II, include environmental effects; public health; global, cultural, and societal aspects; diversity, equity, and inclusion; welfare and safety; and economic factors.

TABLE I. Rubric Used to Assess the Correctness of the Student Solutions to the Design Problem

Rubric Scale	Performance on Correctness
Unsatisfactory	Invalid design: the design does not fulfill any of the given system specifications nor considers design constraints.
Developing	The design does not fulfill one or more major system specifications, and/or fails to identify major constraints.
Satisfactory	The design does not fulfill one or more minor system specifications, and/or does not consider one or more minor design constraints.
Exemplary	The design correctly fulfills all system requirements and identifies major design constraints of the problem.

TABLE II. Rubric Used to Assess the Diversity of the Student Solutions to the Design Problem

Rubric Scale	Performance on Correctness
Unsatisfactory	The design is not unique and does not reflect the personality of the designers.
Developing	The design is not unique and/or does not reflect the personality of the designers.
Satisfactory	The design is divergent and/or reflects the background of one or many students on the team.
Exemplary	The design is divergent and reflects the background of multiple students on the team.

TABLE III. Rubric Used to Assess the Impact of the Student Solutions to the Design Problem on Non-technical Contexts

Rubric Scale	Performance on Correctness
Unsatisfactory	The designer does not consider design impacts sufficiently.
Developing	The designer does not consider major impacts of design.
Satisfactory	The designer does not consider minor design impacts.
Exemplary	The designer correctly considers all major design impacts.

Fig. 2 illustrates the results of the assessment of the 17 designs. Approximately 70% of the teams came up with diverse designs, that reflected their grasp of course contents, their knowledge of related ECE topics that was integrated in their designs. The diverse student backgrounds culminated in diverse solutions, as the researchers noted that there were no replicas of the design, although all 17 designs were solutions to the same problem. Moreover, student teams with more advanced hardware skills have produced more elaborate circuit designs, while student teams with more computer engineers emphasized the software aspect of their solutions.

The researchers noted the degree with which the students reflected upon various impacts of their designs; like economic, environmental, and social impacts; has echoed their conscience and understanding of current universal problems. For example, some student teams have reflected in their report on how their designs have been optimized to reduce the carbon print and have less harmful impact on the environment. Other teams have opted for more economic solutions. Approximately, 59% of the student teams have scored at a satisfactory level, or higher, when considering the impact(s) of their design.

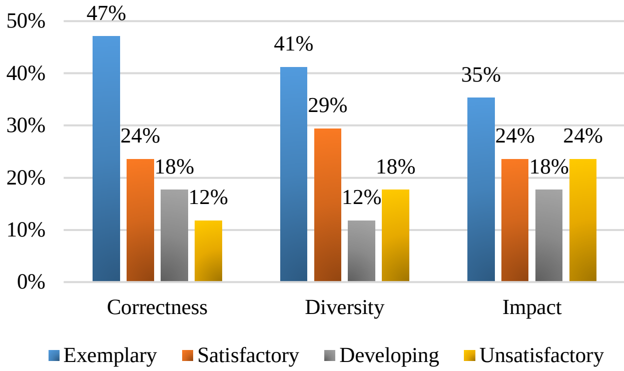

Fig. 2. The results of the design problem 17 sophomore student teams were tasked to complete at the end of Spring 2024. Three metrics were used to assess the designs, namely, the correctness of the design solution; diversity of the solution; and consideration of an impact, or multiple impacts; of their designs in different non-technical contexts.

B. *Student Inclusion*

Indirect assessment of student perspectives on the design problems was conducted through individual surveys, where 52 students were asked about their experience working on the design problem in a team. Fig 3. illustrates the students' response to a Likert scale question. Almost 79% of the students, or above, described working on the design problem in a team as highly non-elitist, non-racist, respectful, and friendly. Approximately, 40% of the students considered working on the design team highly or mildly diverse, while 19% of the students considered this team assignment a homogenous class activity.

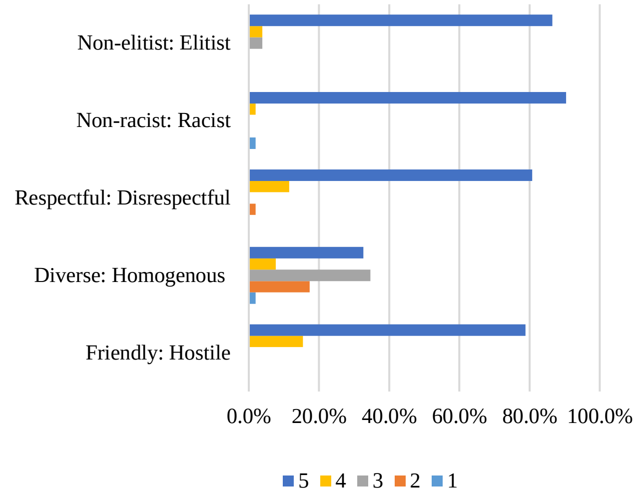

Fig. 3. A Likert scale representation of the students' response to a survey question: "select one option between each set of adjectives that best represents how you would rate working on the design based on your direct experiences."

In another survey question, the students were asked to choose the level of agreement to multiple statements that gage the level of satisfaction to equity and inclusion; illustrated in Fig. 4. The majority of students agreed to the statements: "I felt I was able to perform up to my full potential on the project ," and "I felt valued by my team member(s)," which indicated that sense of equity and self-efficacy gained by respectively 65% and 90% of students from the design problem solving. Only 11.6% of students either agreed, or highly agreed, that their opinions were not valued by their team-mates.

The surveys have further shown that 90.3% had either agreed to, or strongly agreed they felt they were "treated with respect" by their team-member(s), and 88.4% had felt they "belong to the team." These statements reveal that the design problem solving have fostered a great sense of inclusion that the students clearly felt.

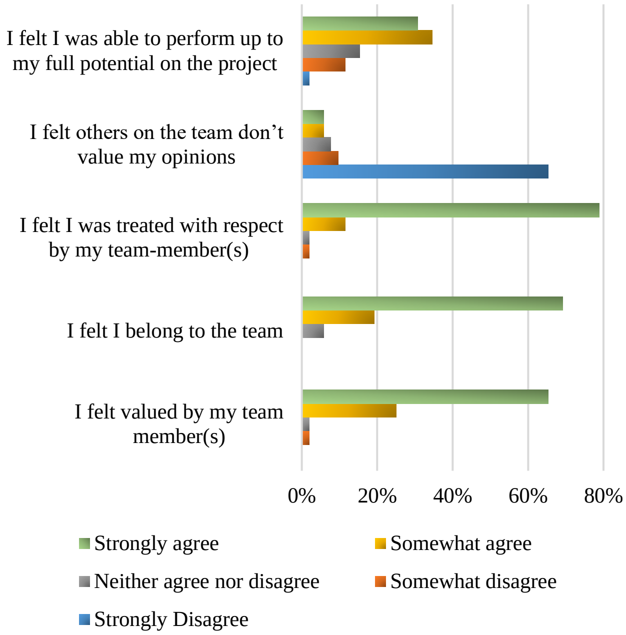

Fig. 4. A representation of the students' response to a survey question: "considering your experiences working on the design project, please indicate your level of agreement with each of the following statements."

IV. Conclusion and Future Work

Design problem solving allows engineering students to use their cognitive skills to produce solutions that are inventive and personable. The creative nature of design problem solving, and the plentiful use of students' cognitive skills, tighten the grasp of students over the course materials, and improve their retention of electrical circuits topics for future use in more advanced courses. While the wide diversity of design solutions promotes diversity, and inclusion, and bolsters students' sense of self-esteem, and self-efficacy.

The instructors noted the diversity of the solutions produced by the students in response to the design problem. Furthermore, it was noted how the students' technical and non-technical backgrounds affected their design choices and their consideration of different impacts of their designs.

The results of the surveys have revealed that the students have found working on a design team a friendly, respectful, non-racist, and non-elitist environment. Moreover, the students have largely considered their design teams' compositions diverse. The surveys also revealed that the overwhelming majority of students have experienced a sense of inclusion and self-equity.

In future work, more data will be generated to correlate design thinking with improving diversity, equity, and inclusion in ECE classes. Design metrics will be dissected deeper to draw profound observations on the diverse solutions that the design problem generates, and how those solutions related to the demographic data collected, including gender and ethnicity, to accurately determine quantitatively the impact of design thinking and problem-solving activity for various demographic groups on self-efficacy, and DEI.

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